GODDARD
GRANT
7N-32-CR
141219
11 P.

COMPARISONS OF DE-1 ENERGETIC ION COMPOSITION DATA AND INCOHERENT SCATTER RADAR DATA

FINAL REPORT

Brenton J. Watkins
Geophysical Institute, University of Alaska
Fairbanks, AK 99775

July 15, 1984 -- December 31, 1985

NAG 5-452

(NASA-CR-182805) COMPARISONS OF DE-1 ENERGETIC ION COMPOSITION DATA AND INCOHERENT SCATTER RADAR DATA Final Report, 15 Jul. 1984 - 31 Dec. 1985 (Alaska Univ.) 11 p

N88-71036

Unclas
00/32 0141219

CONTENTS

1. INTRODUCTION

The objective of this study was to make comparisons of data from the Dynamics Explorer (DE-1) satellite and the Sondrestrom, Greenland Incoherent Scatter Radar. The specific goal was to identify the position of the magnetospheric polar cusp from the DE-1 data, then to search the radar data base for corresponding signatures in the ionospheric data. This work was motivated by the difficulty in identifying the polar cusp from the radar data; it was originally suggested that such comparisons may help in future interpretations of the radar data. The interpretation difficulty with the radar data arises because the cusp ionization has low energies and is deposited in the F-Region ionosphere. The long recombination times at those altitudes, coupled with the horizontal motions from convective electric fields, tends to smear out the ionization making it very difficult to detect with the radar. The ionization from the precipitation is a very small increase over the background. It has been found that the convection velocity and electron temperature are better indicators than the electron density of the cusp location at ionospheric altitudes,and a DE pass that is in close magnetic conjunction with the radar is shown in the next section to illustrate this.

The reason for choosing the energetic ion composition data is that energetic H^+ and He^{++} ions of magnetosheath origin move rapidly down field lines to the ionosphere. The horizontal motions due to convective electric fields are small compared to the downward speeds. Therefore particle observations from DE-1 are a good indicator of the cusp location at ionospheric altitudes; horizontal motions of field lines should not significantly influence the determined cusp locations in the ionosphere.

Two days were initially chosen for study when near magnetic conjunction occurred between the radar and the spacecraft. These days (in April and October 1984) were not entirely ideal because the conjunctions were not as close as really desired. However it was possible during mid 1984 to schedule coordinated observations for November; fortunately, as well as a fairly close conjunction, the data proved quite interesting from a geophysical standpoint. Data from the following days were all examined.

April 24, 1984	1000UT	to	April 25, 1984	1100UT
October 17, 1984	0000 to	2400 UT		
November 14, 1984	0000 to	2400 UT		

We have concentrated our work on the November data because it was the day when the closest magnetic conjuntion occurred, the cusp was near overhead at the Sondestrom Radar

Site, and there was evidence of cusp motions and electron temperature enhancements in the radar data.

2 DATA

2.1 RADAR DATA

The incoherent scatter radar data were acquired using north-south antenna scans in the magnetic meridian plane. An example of the radar parameters, electron density (Ne), electron temperature (Te), ion temperatute (Ti), and ion velocity (vi) are shown in Figure 1. Each antenna scan, which takes approximately five minutes, produces these data over a range of latitudes and altitudes as shown. In the F-region ionosphere, a coverage from 70 to 80 degrees invariant latitude is generally possible, which is about 4 to 5 degrees north and south of the radar latitude of 74 degrees.

Interleaved with the antenna scans that produce data such as that shown in Figure 1, other data were also gathered at fixed positions that are separated in azimuth by a few degrees. These latter data are used to compute the ion convection velocity. Each individual radar integration period in a particular antenna direction gives velocity data in that direction. Therfore these pairs of measurements were used to resolve the vector ion velocities under the assumption that vertical velocities are negligble compared to horizontal velocities. The electric field can then be computed from the ion velocity using the familiar ExB relation. Figure 2 is an example of 24 hours of vector ion velocity data for the day of November 24. The arrows indicate the direction of the ionospheric plasma convection, and the length of the arrows indicates the magnitude of the velocity.

The particular north-south radar scan of Figure 1 was chosen because it clearly indicates the ionospheric effects of the cusp, which in this case is located almost overhead at the radar site at 74 degrees invariant latitude. The upper left panel of Figure 1 is the electron density and very little information can be discerned. There is an obvious F-region peak in the density at about 300 km altitude, but the densities are quite constant with latitude and this is likely a result of the small density enhancement on top of the ambient daytime ionization. The electron temperature in the lower left panel shows a dramatic and unusual enhancement from about 1000 to nearly 4000 degrees. The ion velocity, plotted in the lower right panel, has quite small values overhead, just to the south the yellow portion of the plot indicates westward velocities, and the blue region to the south indicates eastward velocities. Thus the cusp seems to be located in the shear region between oppositely directed plasma flows. On the Figure 2, small boxes indicate the position of the maximum in the electron temperature on some selcted radar scans; it is evident that these locations are all within or near the region of velocity shear.

RADAR DATA

LATITUDE-HEIGHT VARIATIONS

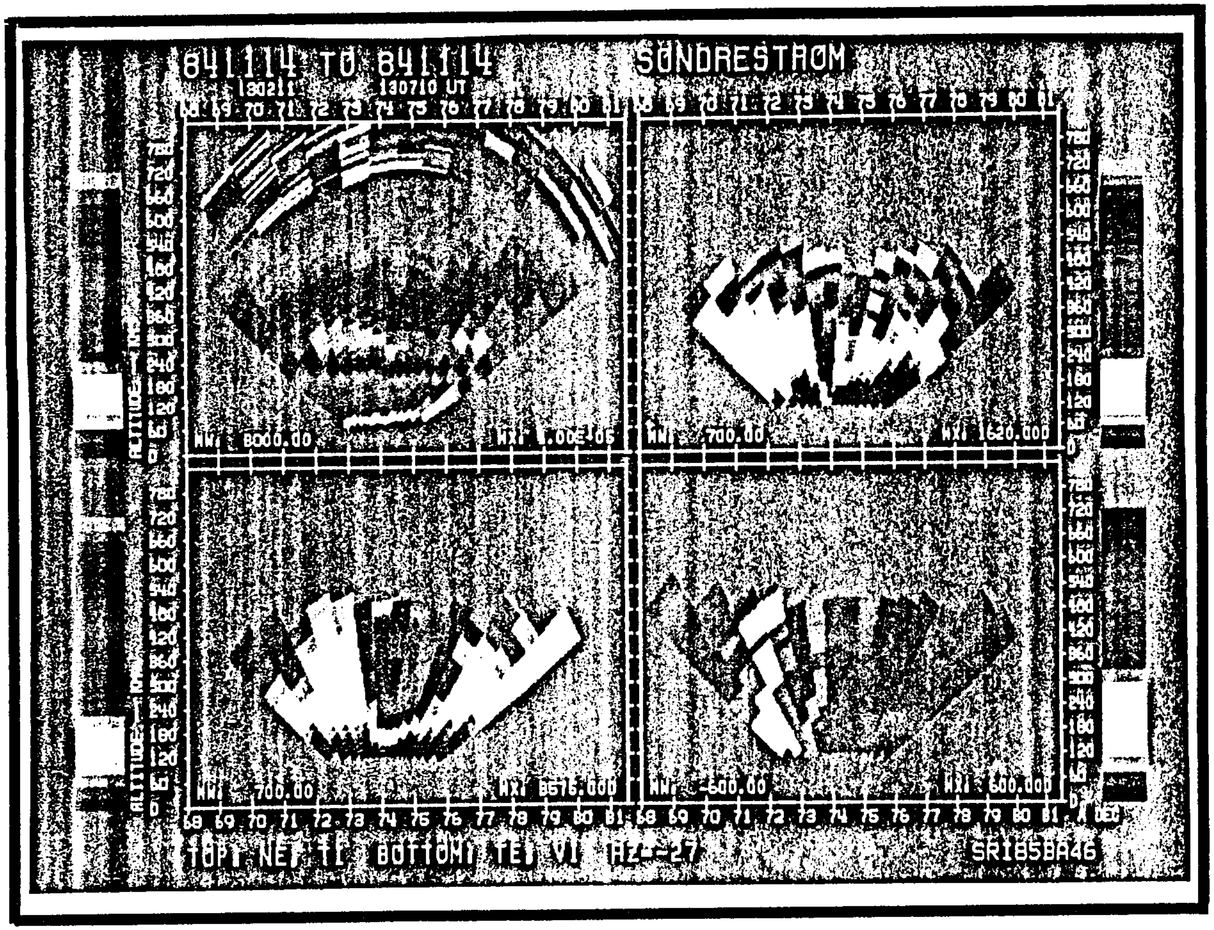
(Example of one north-south scan)

ELECTRON DENSITY

ION TEMPERATURE

3575°K →

700°K →



ELECTRON TEMPERATURE

ION VELOCITY

Figure 1. An example of data from a north-south scan of the Sondestrom Radar. The upper left panel is electron density, upper right is ion temperature, lower left is electron temperature, and lower right is ion velocity.

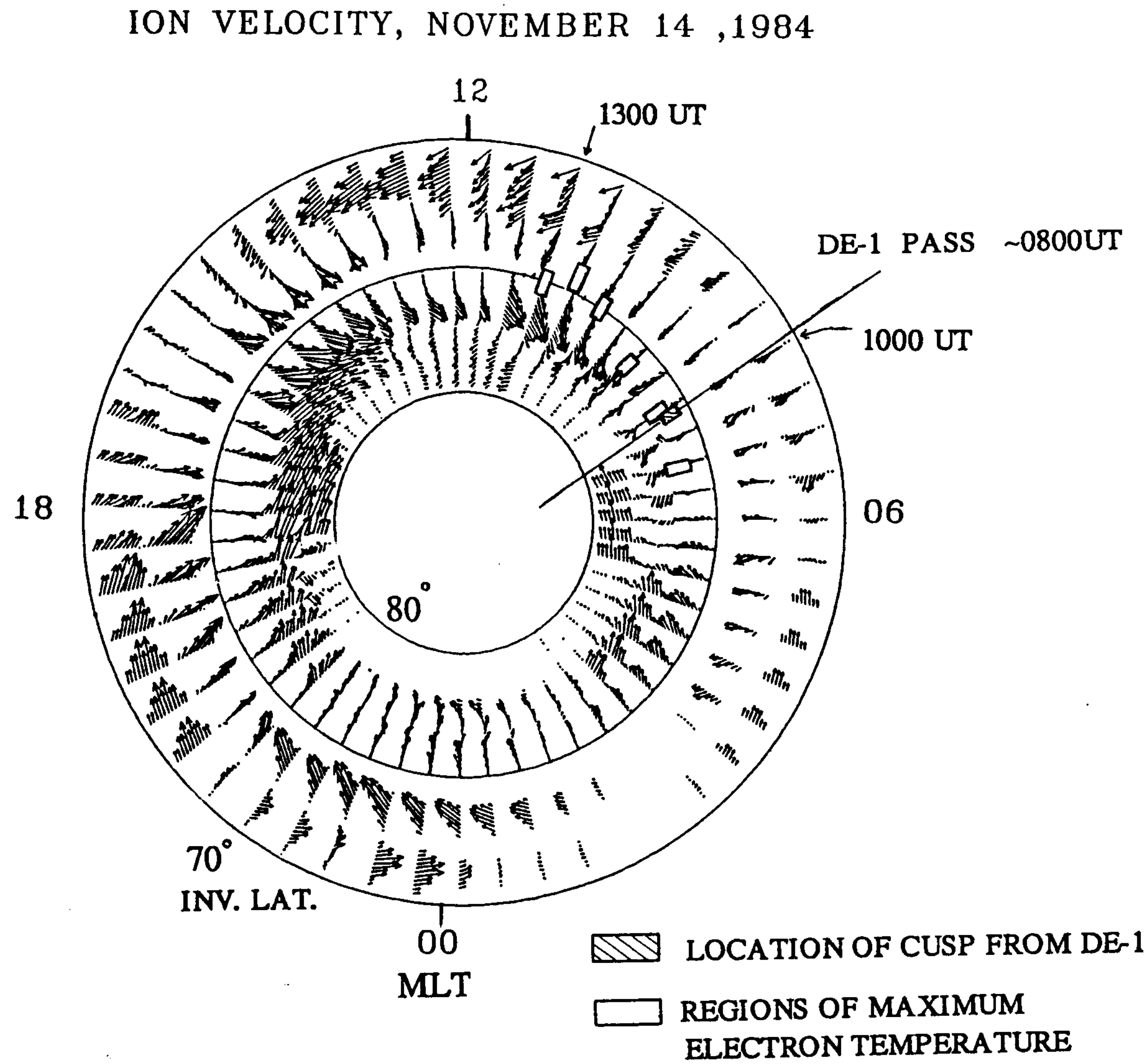


Figure 2. Twenty four hours of velocity data from many north-south scans of the radar antenna. The 6 open boxes denote locations of enhanced electron temperature. The single shaded box denotes the location of the cusp from the DE-1 energetic ion composition data.

This data is unusual because most other data we have examined did not have such striking variations in both the ion velocity and electron temperature. The location of the electron temperature maxima seemed to be relatively constant in latitude, then rapidly moved south, then back north again. It is important to point out that many radar scans from about 1200 MLT displayed no evidence of temperature enhancements, and on Figure 2 we have only plotted positions of enhanced temperature regions where they were clearly evident, and this occurred for the pre-noon cusp times only on this particular day.

It is important to note that several different observations with the radar in the past by various experimenters have shown the ionospheric features we have seen, viz occasional large electron temperature enhancements, and east-west velocity shears in the vicinity of the dayside auroral oval. Although it has been tempting to associate these with the magnetospheric cusp, direct comparisons with other experimental techniques have not been possible. The cusp position from the DE data seems to confirm a direct correspondence with the electron temperature enhancements, at least in this case.

2.2 DE-1 DATA

The Figure 3 shows a spin phase angle-time spectrogram for the particular DE-1 pass that was in near magnetic conjunction with the radar on November 14, 1984. The three data sets are for H^+ (top panel), O^+ (center panel), and He^{++} (lower panel). Unfortunately no O^+ data was acquired, however the H^+ ion composition data is sufficient for our purposes. The spin angle is denoted on the vertical axis; over the polar cap the magnetic field makes an angle of about 90 degrees with the satellite velocity direction, therefore ions flowing up the magnetic field lines from the ionosphere are near 90 degrees. The fluxes are color coded as shown. There are low energy H^+ ions seen over the entire pass, and also upflowing ions over much of the data period. The times of enhanced ion flux, which is assumed to be magnetosheath plasma, indicates the magnetospheric cusp. The sharp onset and cutoff of these fluxes correspond to latitudes that specify the cusp position; it is this position of enhanced fluxes that is marked on figure 1. The He^{++}ion fluxes show similar behavior but there is no evidence of upflow like the H^+ ions.

3. COMPUTATION OF HEAT FLUX

We also used the radar data to compute the magnetospheric heat flux downward into the ionosphere. It was considered that this may be a better indication of the cusp than the electron temperature alone because it depends on both the electron temperature and the electron density. Although the temperature enhancements were very clear at times, there were many radar scans after local noon that did not indicate similar temperature peaks. It

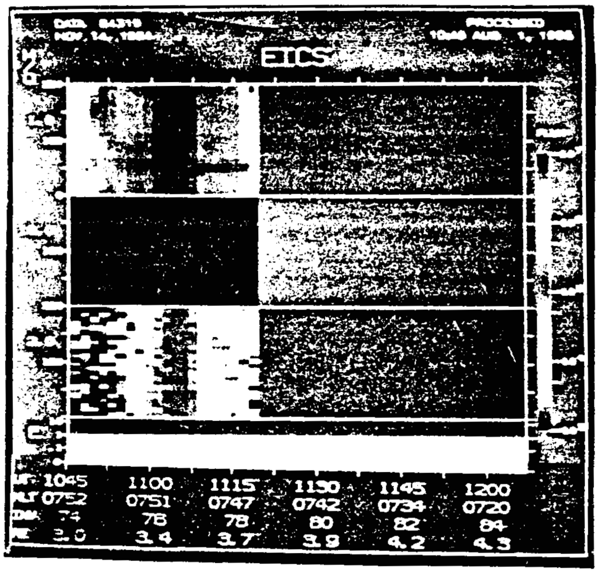


Figure 3. Spin phase angle-time spectrogram for the DE-1 pass that was in near magnetic conjunction with the radr on November 14, 1984.

was hoped that the heat flux may produce easier to identify signatures. This turned out not to be the case, nevertheless the values computed are of aeronomical importance because they attain quite high values for short times. The figure 4 shows heat flux profiles over a range of latitudes for two different north-south scans of the radar. Variations from about $2x10^9$ to nearly $1x10^{11}$ $eV/cm^2/s$ are observed. Such variations are likely to affect the ion heating in an irrregular manner because of the intermittent nature of the variations.

4. CONCLUSIONS

We conclude that the electron temperature enhancements that occur in the ionosphere at the cusp latitudes are directly connected to the magnetospheric cusp field lines. The temperature enhancements, when they occur, are sharply peaked, covering only 1 to 1.5 degrees of latitude. For the example studied, the cusp location from the DE-1 pass was almost coincident with the location determined from the radar. The cusp position was found to be time dependent which is likely due to variations of the interplanetary magnetic field. It was also noted that the cusp location was close to the region of east-west velocity shear. The cusp was in the central region with small ion convection velocities. However, the convection velocities derived from radar are often quite variable and difficult to fit to a consistent pattern, probably because of the consistent short-term variability. The electron temperature seems to be the best indicator of the cusp from the ground based radar observations and it is suggested that future analysis efforts concentrate on this parameter.

As a final comment we would like to make a suggestion for possible future work. If more DE-1 data were available during close conjunctions with the radar, we suggest that it would be very interesting to determine whether if any special ionospheric conditions occur when upflowing ions are present. For example, sudden enhanced convection is a possible mechanism to accelerate ions upward; appropriate radar data should be able to provide the electric field data. However, to make such an effort worthwhile many cases should be studied; it is uncertain that enough conjunctions exist in the DE data base because the radar typically operates only a few days per month.

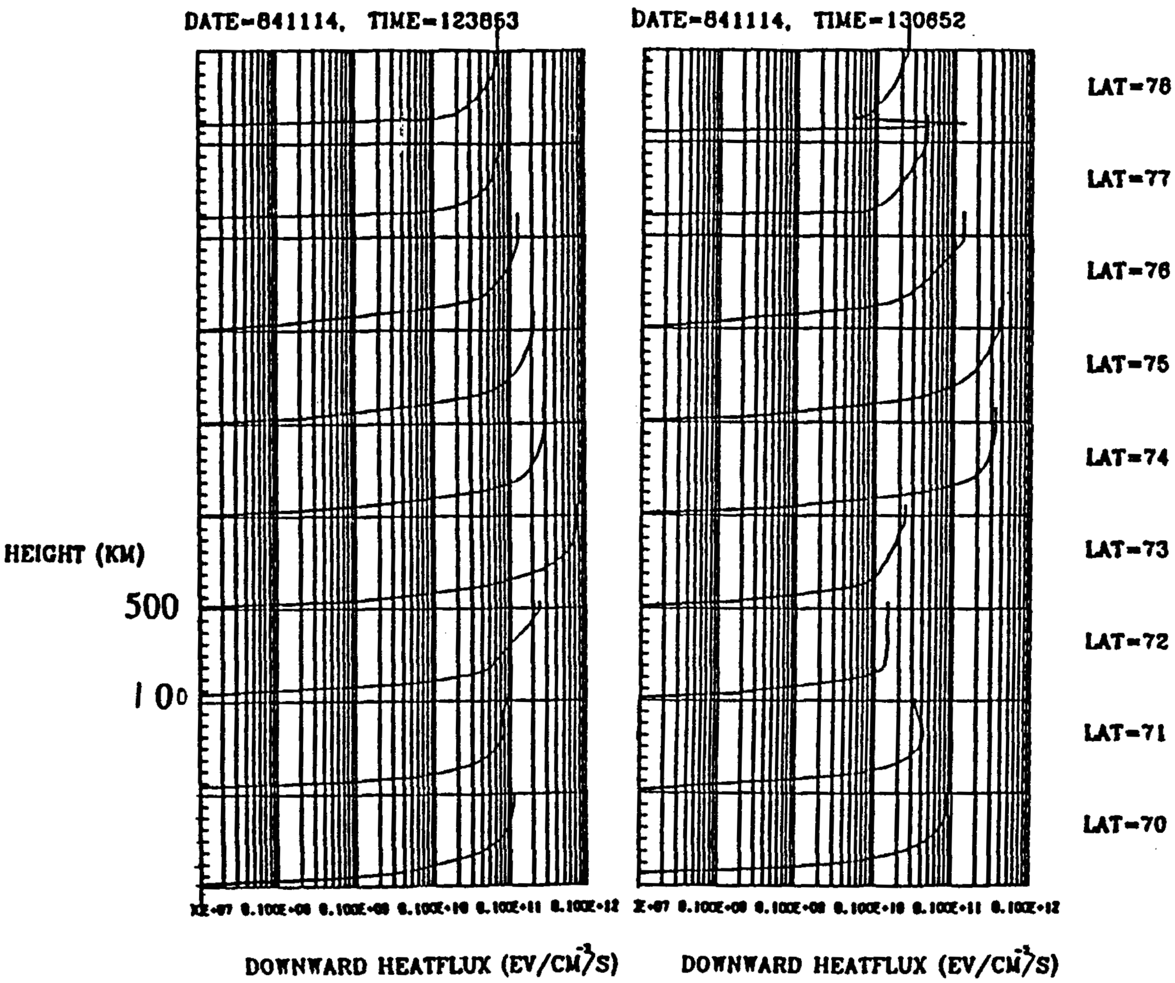


Fig. 4. The Examples of Calculated downward heat flux height profiles from latitudes 70-80 degrees(maximum at 73-75 degrees) at two times 1239 and 1307 UT.

5. CONFERENCE PAPERS AND JOURNAL PUBLICATION

Papers have been presented at two scientific conferences.

(1) 'Comparisons of DE-1 satellite ion composition and Sondrestrom Radar data', American Geophysical Union meeting, December 1985.
by B.J.Watkins and W.K.Peterson.

(2) 'Heat flux into the thermosphere at cusp latitudes',IUGG General Assembly, Vancouver, 1987.
by K.J.Yang, B.J.Watkins, and W.K.Peterson.

The following paper has been prepared for submission to Geophysical Research Letters.

(1) 'Identification of the Magnetospheric Cusp from Incoherent Scatter Radar and DE-1 Data'.
by Yang, Watkins and Peterson.